Understanding Forensic DNA Analysis

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UNDERSTANDING FORENSIC DNA ANALYSIS

Leverhulme Research Centre
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UNDERSTANDING FORENSIC DNA ANALYSIS

Welcome to the second issue in our Understanding Forensic Analysis series of comics! These have been created by the Leverhulme Research Centre for Forensic Science and The Scottish Centre for Comics Studies at the University of Dundee and are based on the judicial primers produced in collaboration between members of the judiciary, the Royal Society, and the Royal Society of Edinburgh.

The Lord Chief Justice of England and Wales and the Lord President of Scotland have worked together with the Royal Society and the Royal Society of Edinburgh to create a series of judicial primers to assist the judiciary with better understanding of scientific evidence in the courtroom. They were written by leading scientists and members of the judiciary, and peer reviewed by practitioners, scientists and judges. The aim of the primers is to present clear, scientifically accurate information and to address the limitations and challenges associated with applying scientific evidence in a courtroom. The Understanding Forensic Analysis comic series led by the Leverhulme Research Centre for Forensic Science at the University of Dundee reinterprets the primers in order to visualise these issues and challenges for a wider audience.

Understanding Forensic DNA Analysis is an examination of the use of DNA as forensic evidence. It explores current practice and considerations in interpretation of DNA evidence as well as considering new methods that are being developed.

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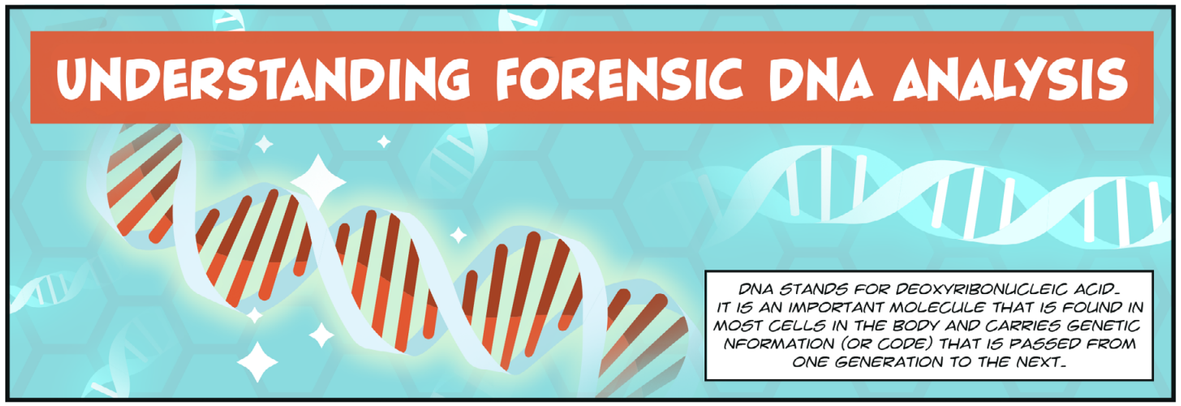
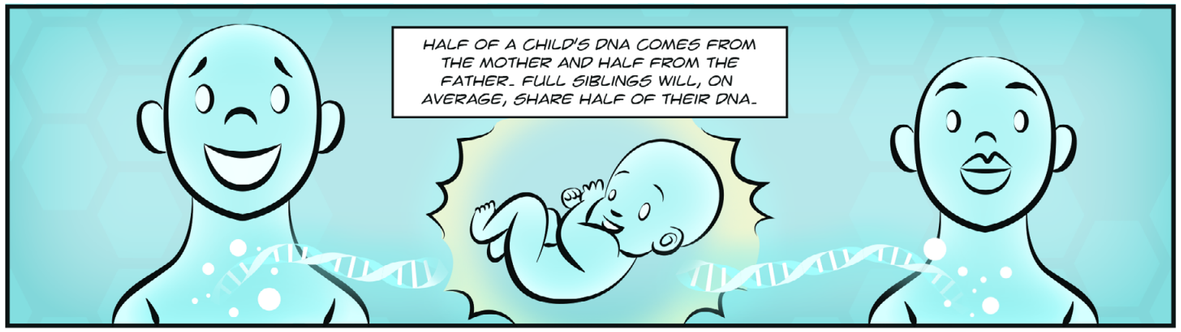
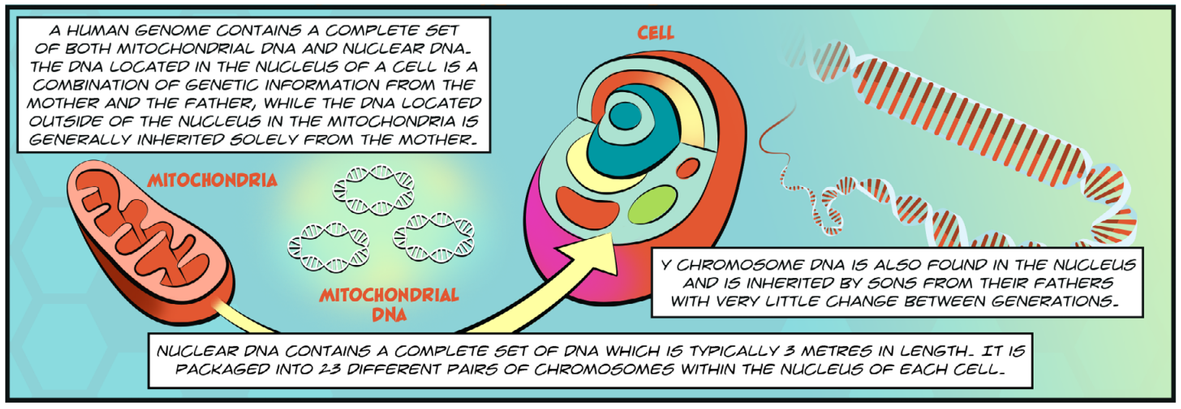
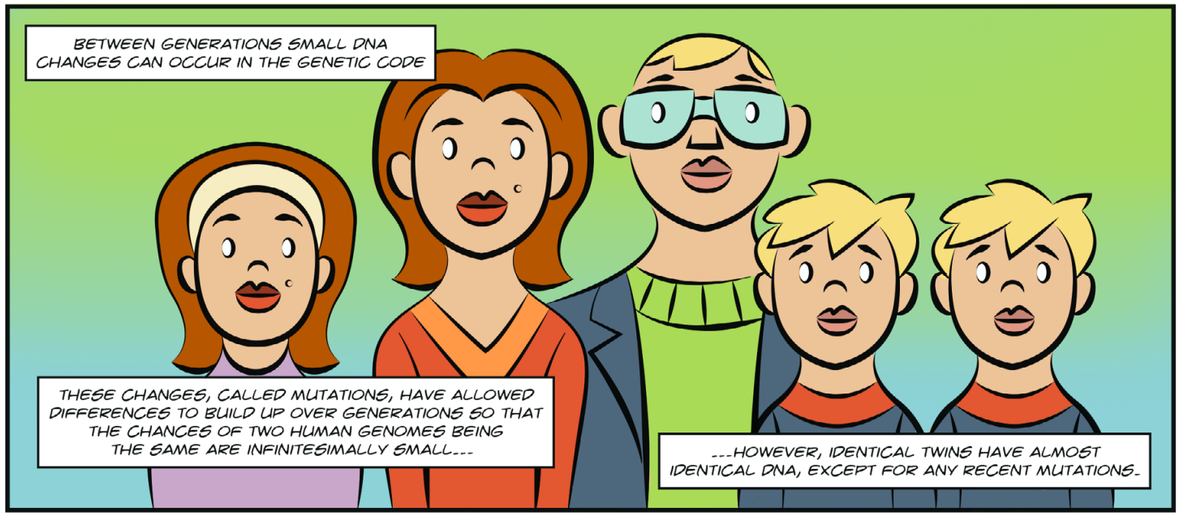
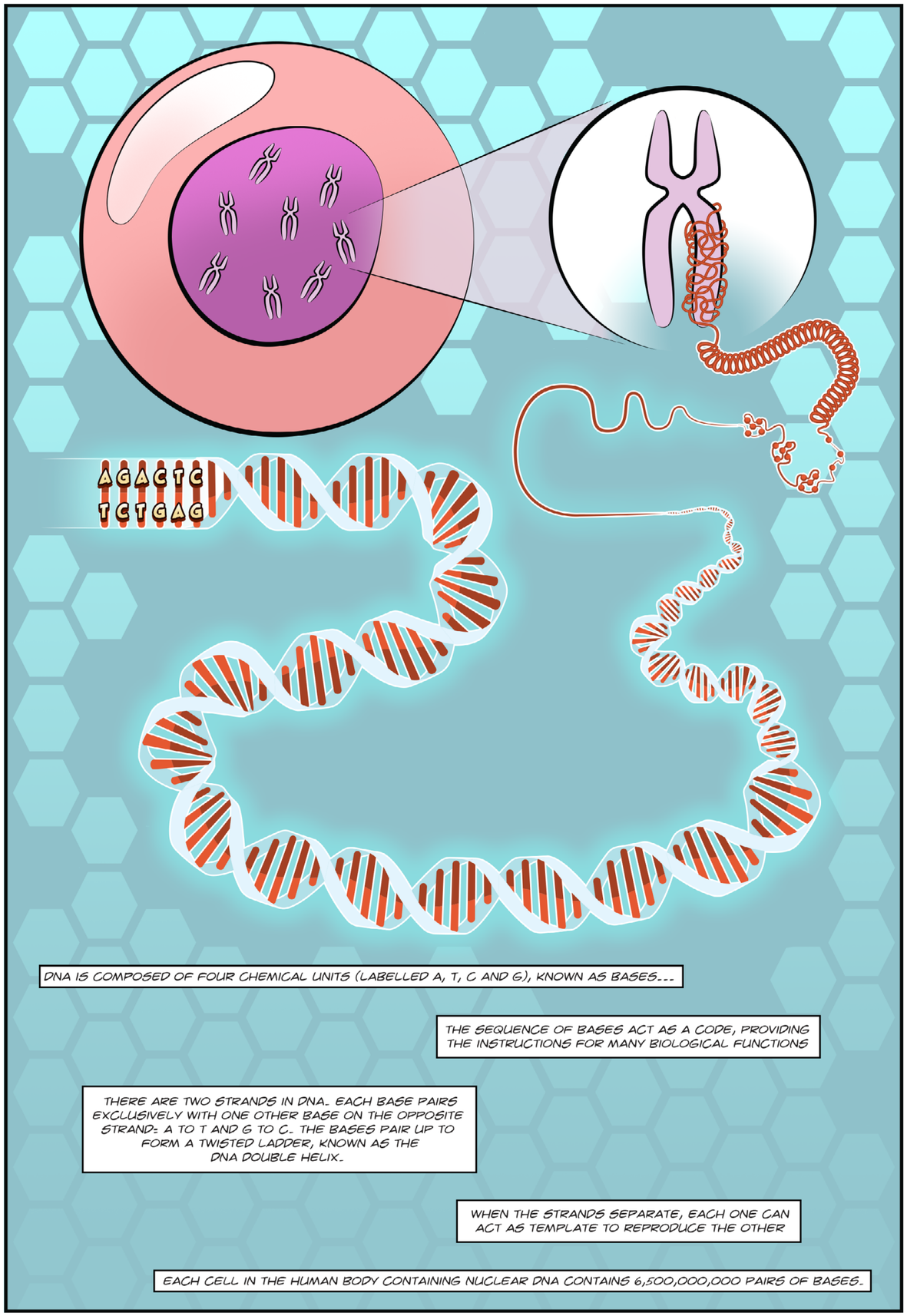
The Scottish Centre for Comics Studies (SCCS) leads a research project on the use of comics for educational purposes. It has, in collaboration with various private, public and third sector partners, and working with other researchers, produced comics that communicate the findings of research, or engage the public with important issues related to healthcare, science communication, and social justice. We are proud to be working with the Leverhulme Research Centre for Forensic Science to produce these comics based on the judicial primers.











DNA IS COMPOSED OF FOUR CHEMICAL UNITS (LABELLED A, T, C AND G), KNOWN AS BASES...

THE SEQUENCE OF BASES ACT AS A CODE, PROVIDING THE INSTRUCTIONS FOR MANY BIOLOGICAL FUNCTIONS

THERE ARE TWO STRANDS IN DNA. EACH BASE PAIRS EXCLUSIVELY WITH ONE OTHER BASE ON THE OPPOSITE STRAND: A TO T AND G TO C. THE BASES PAIR UP TO FORM A TWISTED LADDER, KNOWN AS THE DNA DOUBLE HELIX.

WHEN THE STRANDS SEPARATE, EACH ONE CAN ACT AS TEMPLATE TO REPRODUCE THE OTHER

EACH CELL IN THE HUMAN BODY CONTAINING NUCLEAR DNA CONTAINS 6,500,000,000 PAIRS OF BASES.

DEFINING DNA AND ITS USE IN FORENSIC SCIENCE

SINCE 1984, CONSIDERABLE SCIENTIFIC STUDY AND RESOURCE HAS BEEN DEVOTED TO THE DEVELOPMENT AND REFINEMENT OF DNA ANALYSIS TECHNOLOGIES.

IN FORENSIC DNA ANALYSIS ONLY SMALL SECTIONS OF A PERSON'S DNA ARE ANALYSED BY FORENSIC SCIENTISTS.

DEFINING DNA AND ITS USE IN FORENSIC SCIENCE

FORENSIC DNA ANALYSIS TYPICALLY ASSESSES SPECIFIC LOCATIONS ON THE NUCLEAR DNA, CALLED **LOCI**, WHERE THERE ARE REPEATING BLOCKS OF THE FOUR BASES (A, T, C AND G). THESE ARE CALLED SHORT TANDEM REPEATS OR **STRS**. THE NUMBER OF REPEAT BLOCKS CAN VARY BETWEEN INDIVIDUALS.

THE DNA ANALYSIS MEASURES THE NUMBER OF REPEATING BLOCKS (THE **STRS**) AT THESE LOCATIONS (THE **LOCI**). EACH DIFFERENT VARIANT IS CALLED AN **ALLELE** AND AN INDIVIDUAL WILL INHERIT ONE **ALLELE** FROM EACH PARENT.

8 REPEATING UNITS

CTAG GATA GATA GATA GATA GATA GATA GATA GATA CTAG CTAG CTAG CTAG **PERSON 1**

9 REPEATING UNITS

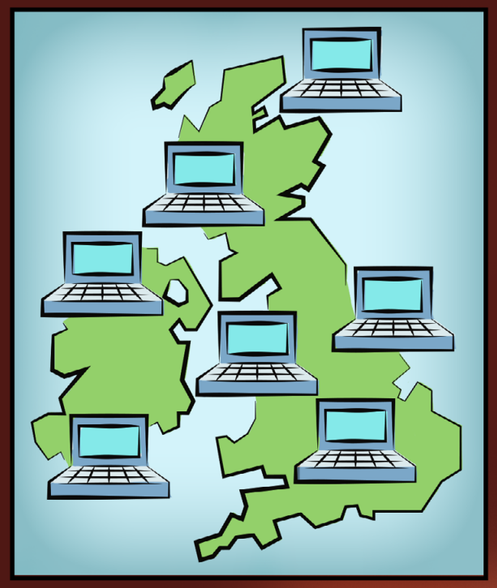
CTAG GATA GATA GATA GATA GATA GATA GATA GATA GATA CTAG CTAG CTAG **PERSON 2**

10 REPEATING UNITS

CTAG GATA GATA GATA GATA GATA GATA GATA GATA GATA GATA CTAG CTAG **PERSON 3**

THERE ARE A NUMBER OF MUTATIONS THAT AFFECT THE NUMBER OF REPEATS WITHIN EACH LOCI. AS A CONSEQUENCE, THERE ARE USUALLY SEVERAL DIFFERENT ALLELES FOR EACH DNA LOCI, EACH WITH SLIGHTLY DIFFERENT REPEAT LENGTHS.

THE FREQUENCY OF OCCURRENCE OF A SPECIFIC ALLELE PROVIDES A MEASURE OF HOW COMMON THAT ALLELE IS IN THAT POPULATION. SINCE 2014, IN THE UK 16 LOCI ARE EXAMINED. IN SOME SCOTTISH CASES 23 LOCI ARE EXAMINED.



IN 1995 THE UK NATIONAL DNA DATABASE WAS ESTABLISHED TO MAXIMISE THE INVESTIGATIVE USE OF DNA PROFILES FROM INDIVIDUALS AND FROM CRIME SCENES. ON A GLOBAL SCALE, MOST COUNTRIES NOW USE FORENSIC DNA ANALYSIS IN ONE FORM OR ANOTHER.

THE MAIN QUESTIONS RELATING TO DNA EVIDENCE ARE:

1. WHO COULD A DNA SAMPLE RECOVERED FROM A CRIME SCENE OR A VICTIM HAVE ORIGINATED FROM?
2. IF THE SAMPLE HAS ORIGINATED FROM A BODY FLUID, THEN WHICH ONE?
3. HOW DID THE DNA GET TO WHERE IT WAS RECOVERED FROM?
4. HAVE THE RESULTS BEEN REPORTED IN A FAIR AND BALANCED WAY?

PROVIDED THERE IS SUFFICIENT DNA, THE INTERPRETATION OF A DNA PROFILE FROM A SINGLE INDIVIDUAL'S SAMPLE IS STRAIGHTFORWARD AND CAN PROVIDE POWERFUL SCIENTIFIC EVIDENCE EITHER TO EXCLUDE OR TO INCLUDE ANY ONE INDIVIDUAL AS A POSSIBLE SOURCE OF THAT DNA.

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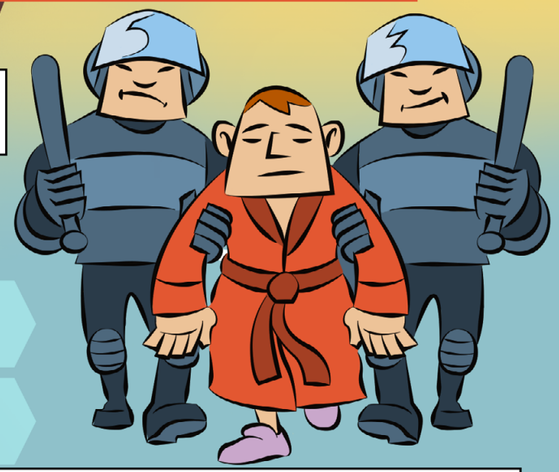
SAMPLES CAN CONTAIN DNA FROM MULTIPLE PEOPLE (MIXED PROFILES). TECHNOLOGICAL IMPROVEMENTS IN DNA ANALYSIS HAVE RESULTED IN THE ABILITY TO DETECT EVER SMALLER QUANTITIES OF DNA. THIS HAS LED TO INCREASED NUMBERS OF MIXED DNA PROFILES.

THIS MEANS THAT IT IS IMPORTANT TO;
1. UNDERSTAND AND CONTROL CONTAMINATION AND
2. BE ABLE TO INTERPRET MIXED DNA PROFILES.

DNA EVIDENCE IS INTERPRETED BY CALCULATING AND PRESENTING A ***LIKELIHOOD RATIO***. THAT IS BY CALCULATING STATISTICALLY, HOW RARE ANY MATCHING DNA PROFILE IS IN A POPULATION.



A VARIETY OF COMPUTER SOFTWARE PROGRAMS HAVE BEEN DEVELOPED FOR THE INTERPRETATION OF MIXED PROFILES, USING A RANGE OF MATHEMATICAL METHODS.

THIS MEANS THAT WHEN A LIKELIHOOD RATIO IS ESTIMATED FROM A DNA PROFILE USING DIFFERENT SOFTWARE APPROACHES, DIFFERENT VALUES CAN BE OBTAINED.

IN THE UK, THE NATIONAL ACCREDITATION BODY AND THE FORENSIC SCIENCE REGULATOR'S CODES OF PRACTICE AND CONDUCT SETS OUT THE REQUIREMENTS FOR THE VALIDATION OF SOFTWARE PROGRAMS USED FOR MIXED DNA SAMPLE INTERPRETATION.

THERE IS A DEVELOPING SCIENTIFIC RESEARCH BASE ON THE EVALUATION OF HOW DNA TRANSFERS ONTO AN ITEM AND THE LENGTH OF TIME IT MIGHT PERSIST.

DNA SCIENTISTS RELY ON THE PUBLISHED SCIENTIFIC LITERATURE AS WELL AS ON THEIR EXPERIENCE AND KNOWLEDGE OF THE AVAILABLE UNDERLYING CIRCUMSTANCES OF EACH CASE.

BUT! NOT ALL CONTACT WILL RESULT IN A DNA TRANSFER AND THE AMOUNT OF DNA THAT CAN TRANSFER IN EACH SITUATION WILL DEPEND ON A VARIETY OF FACTORS, INCLUDING:

1. PERSON TO PERSON VARIABILITY
2. HOW LONG THE TOUCH WAS FOR, WHETHER SWEAT OR BODY FLUIDS WERE INVOLVED AND WHAT HAS BEEN DONE SINCE SUCH AS WASHING OF HANDS OR BODY
3. THE INTENSITY OF CONTACT (FOR EXAMPLE, A BRIEF TOUCH OR A ROBUST HANDSHAKE)
4. WHETHER SURFACES ARE WET OR DRY, ROUGH OR SMOOTH, ABSORBENT OR NON-ABSORBENT.

AND!

IT IS OFTEN NOT POSSIBLE TO DETERMINE WHEN THE DNA WAS DEPOSITED (DNA COULD PERSIST FOR MANY MONTHS IN IDEAL CONDITIONS DEPENDING ON A RANGE OF VARIABLES).

INDIRECT TRANSFER CAN OCCUR FROM PERSON TO PERSON, PERSON TO OBJECT OR OBJECT TO OBJECT. THIS IS ALSO CALLED SECONDARY OR TERTIARY TRANSFER AND CAN RESULT IN A PERSON'S DNA BEING ON AN OBJECT THAT THEY HAVE NOT DIRECTLY TOUCHED.

UNDER SOME TEST CONDITIONS, IT HAS BEEN FOUND THAT; 1) A PERSON'S DNA CAN BE INDIRECTLY TRANSFERRED ONTO AN OBJECT THAT THEY HAVE NEVER HAD CONTACT WITH BY ANOTHER PERSON WITHOUT DETECTING THE DNA OF THE PERSON WHO ACTUALLY HAD CONTACT WITH THE OBJECT; 2.) WITH EACH TRANSFER EVENT THE AMOUNT OF DNA TRANSFERRED DECREASES, 3) DNA CAN ALSO BE REMOVED FROM THE SURFACE OF AN OBJECT WHEN IT IS TOUCHED.

IF A DNA 'MATCH' IS OBSERVED BETWEEN A SUSPECT'S DNA PROFILE AND THE DNA PROFILE OF EVIDENCE RECOVERED FROM A CRIME SCENE THEN 3 POSSIBILITIES EXSIST;

1. THE SUSPECT DEPOSITED THE SAMPLE.

2. THE SUSPECT DID NOT DEPOSIT THE SAMPLE BUT HAS THE PROFILE BY CHANCE. THE PROBABILITY OF OBTAINING THIS MATCH BY CHANCE IS EXPRESSED AS A LIKELIHOOD RATIO.

3. THE SUSPECT DID NOT PROVIDE THE SAMPLE AND THE MATCHING RESULT IS A FALSE POSITIVE DUE TO SOME KIND OF ERROR, CONTAMINATION, OR INDIRECT TRANSFER.

SCIENTISTS ADDRESS ISSUES OF ERROR AND CONTAMINATION THROUGH STRINGENT QUALITY CONTROL PROCESSES, CHECKS AND CONTROL SAMPLES ASSOCIATED WITH THEIR WORK.

TRANSFER OF DNA AND ITS PERSISTENCE REMAINS THE SUBJECT OF CONTINUING RESEARCH.

FORENSIC DNA ANALYSTS ARE TRAINED, MONITORED AND AUDITED IN ORDER TO MAINTAIN STANDARDS AND ENSURE THAT THE RESULTS OBTAINED ARE ROBUST AND RELIABLE.

FORENSIC DNA ANALYSIS HAS BEEN ESTABLISHED AS A CORE SCIENTIFIC TECHNIQUE SINCE THE MID-1980S AND HAS BEEN USED WIDELY IN THE UK COURTS AND MANY COURTS AROUND THE GLOBE. ITS UNDERPINNING SCIENCE IS RELIABLE, REPEATABLE AND ACCURATE, BASED ON VALIDATED TECHNOLOGY AND TECHNIQUES FOR BOTH THE GENERATION OF A DNA PROFILE AND THE INTERPRETATION OF THAT PROFILE.

WHEN FORENSIC DNA ANALYSIS IS USED AS EVIDENCE IN COURT, THE FOLLOWING SHOULD BE CONSIDERED:

WHEN A DNA PROFILE IS OBTAINED FROM ONE PERSON, THE INTERPRETATION OF THAT DNA PROFILE IS NORMALLY STRAIGHTFORWARD AND PROVIDES POWERFUL SCIENTIFIC EVIDENCE TO EITHER EXCLUDE OR INCLUDE AN INDIVIDUAL AS A POSSIBLE SOURCE OF THE DNA.

DNA PROFILES CAN EXCLUDE PEOPLE AND CAN PROVIDE LINKS BETWEEN PEOPLE, BETWEEN PEOPLE AND PLACES, AND PEOPLE AND OBJECTS. THE WEIGHT OF EVIDENCE FROM MIXED DNA PROFILES IS CALCULATED USING COMPUTER SOFTWARE. THERE ARE A RANGE OF SOFTWARE PROGRAMS AVAILABLE, WHICH USE DIFFERENT ASSUMPTIONS AND STATISTICAL METHODS TO ANALYSE THE MIXED DNA PROFILES AND TO PRODUCE 'UNMIXED' PROFILES. THIS MEANS THAT:

1. THE SAME DATA DERIVED FROM MIXED DNA PROFILES ANALYSED REPETITIVELY BY THE SAME SOFTWARE CAN HAVE SMALL DIFFERENCES IN THE RESULTING 'UNMIXED' DNA PROFILES.

2. THE SAME DATA DERIVED FROM MIXED DNA PROFILES ANALYSED BY DIFFERENT SOFTWARE PROGRAMS CAN HAVE MORE MARKED DIFFERENCES IN THE RESULTING 'UNMIXED' DNA PROFILES.

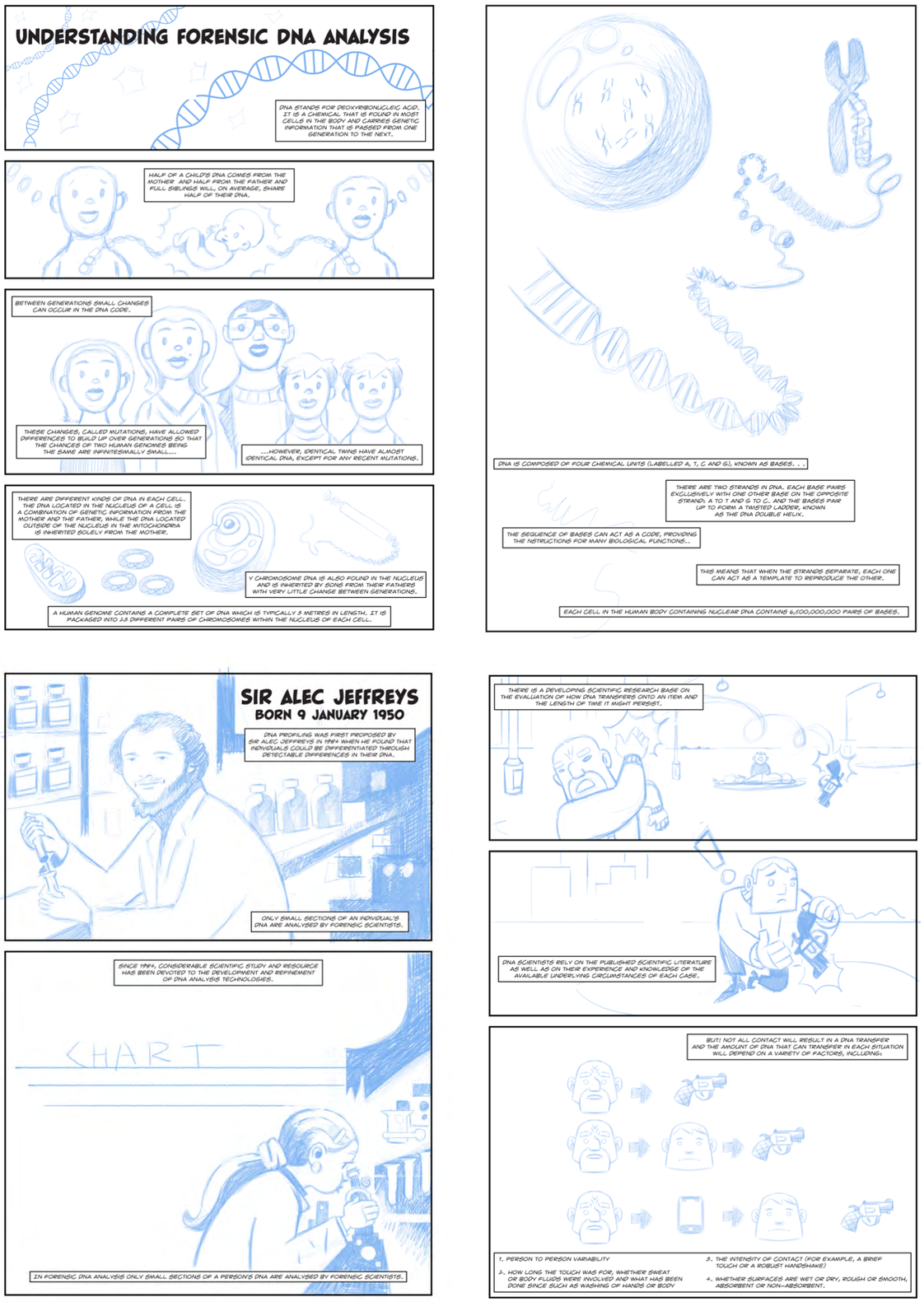
THE ANALYSIS AND INTERPRETATION OF DNA PROFILES IS UNDERTAKEN ONLY WITHIN VALIDATED GUIDELINES BY THE ORGANISATION PERFORMING THE WORK.

SOME TESTS TO DETERMINE WHICH BODY FLUID(S) MAY HAVE PRODUCED A DNA PROFILE ONLY GIVE AN INDICATION AS TO THE POSSIBLE PRESENCE OF A BODY FLUID AND NOT A DEFINITE IDENTIFICATION, BUT MORE RESEARCH IS BEING DONE IN THIS AREA. A SCIENTIST MAY GIVE AN OPINION ON THE PRESENCE OF A PARTICULAR BODY FLUID BY CONSIDERING: THE RESULT OF A CHEMICAL TEST, THE PHYSICAL APPEARANCE OF A STAIN, THE QUANTITY OF DNA RECOVERED AND THE QUALITY OF THE DNA PROFILE OBTAINED.

THERE ARE MANY PUBLISHED STUDIES ADDRESSING THE TRANSFER AND PERSISTENCE OF DNA BUT SPECIFIC CIRCUMSTANCES RELATING TO INDIVIDUAL CRIMINAL CASES ARE NOT LIKELY TO HAVE BEEN STUDIED. THIS IS ALSO AN AREA OF ACTIVE RESEARCH.

THE USE OF DNA EVIDENCE IS AN EXTREMELY SUCCESSFUL TOOL IN CRIMINAL INVESTIGATIONS, AND SCIENTISTS ARE EXPLORING NEW DNA METHODS, WHICH MAY, FOR EXAMPLE, ENABLE PREDICTION OF AN INDIVIDUAL'S SKIN OR EYE COLOUR.

THUMBNAILS



BIOGRAPHIES

CHRIS MURRAY is Chair of Comics Studies and the Associate Dean for Knowledge Exchange and Partnerships at the *University of Dundee*. He is Director of the *Scottish Centre for Comics Studies* and *Dundee Comics Creative Space*. Murray co-edits *Studies in Comics*. He researches British comics, superhero comics and public information comics.
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PHILLIP VAUGHAN is a Senior Lecturer and Programme Director at the *University of Dundee*. He has worked with the *BBC*, *Sony*, *DC Comics*, *Warner Bros* and *EIDOS*. He has credits on work such as *Braveheart*, *Farscape*, *Star Trek*, *Wallace and Gromit*, *Tom & Jerry*, *Commando* and *Superman*. He currently hosts a podcast for *Comic Scene Magazine*.
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Her research interests are graphic justice, critical theory, trauma and memory studies. Her monograph, entitled *Representation and Memory in Graphic Novels* (2019) is available from Routledge.
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LAURA FINDLAY is a project coordinator at Screen Education Edinburgh. She has worked on a number of public information comics, such as *The Gift: Transforming Lives Through Organ Donation;* her most recent comic is about the Golden State Killer. Her research interests include non-verbal communication through sound and image and representation in true crime narratives.

MARK BROWN graduated from Duncan of Jordanstone College of Art and Design, before moving to London where he cut his teeth creating content across various platforms. He has worked for *The BBC*, *Channel 4*, *The Daily Telegraph*, *Digit4*, *University of York*, *University of Dundee*, *HighScore TV*, *Original Gravity*, *The McManus Gallery* and *Firewords Quarterly*.
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NIAMH NIC DAEID is Director of the award winning *Leverhulme Research Centre for Forensic Science (LRCFS)*. The 10 year mission is to provide a robust underpinning for the scientific evidence presented in our Courts. She is a Chartered Chemist and an authorised Forensic Chemist with specialisms including fire investigation, clandestine drug chemistry and explosives.
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